Testing Design of a Social Innovation
The Environmental Mitigation Banking System

Khalid Saeed
Professor of Economics and System Dynamics
Department of Social Science and Policy Studies
Worcester Polytechnic Institute, USA
Email: saeed@wpi.edu

Atsushi Fukuda
Associate Professor of Transportation Engineering
Nihon University, Japan
Email: fukuda@trpt.cst.nihon-u.ac.jp

Abstract

This paper attempts to evaluate the performance of an environmental mitigation banking system operating under different regulatory. Pricing and subsidization policies using system dynamics modeling and computer simulation. Pricing of credits is an important aspect of the banking system and complex engineering methods connecting cost to price and market have been proposed as pricing criteria. Also, subsidization of the mitigation system by the government is often advocated by environmental groups. The analysis of this paper suggests that the market is able to yield an optimal price with or without inputs from engineering methods connecting price to cost. Also, the system operates best without yielding overshoot in infrastructure development when operated without any subsidies. The experimental process used to test the efficacy of the mitigation banking system is seen in general to be important to the design of social innovations direly needed for the smooth functioning of the modern day complex societal system.

1. Introduction

As long as the scale of human settlements was small, and the resource basket used was constituted mostly by locally found renewable resources, the resource limits remained easily recognizable. It is not surprising that indigenous knowledge in traditional societies enabled them to live in a way that maintained a balance between development and environment. For example, ancient agricultural methods, such as slash-and-burn farming were restricted to small ranges, desert cultures adopted nomadic ways to assure regeneration of the oases that sustained them, planting trees was a believed to earn spiritual merit, and fallow practice and diversity of crops were widely used as standard faming practices that sustained land fertility.

The indigenous knowledge and beliefs at that scale allowed the human society to live in harmony with nature and the questions of conquering it or sustaining it did not arise [4]. As technological developments allowed access to huge stocks of nonrenewable resources that seemed to be unlimited [10, 11], and this together with the availability of modern transportation networks allowed the scale of the human settlements to grow, multiple societal functions had to be broken away from individual roles to become resident in specialized institutions for the sake of expediency. Unfortunately, the societal function of environmental responsibility that came naturally to small-scale societies with holistic individual roles fell through specialization cracks since institutions taking over this function were never thought about until evidence of deterioration in environment appeared. The impending danger of disaster that can be created by indiscriminate growth and resource consumption raised some thirty years ago by the famous “Limits to Growth” study [6] is now quite widely recognized [2, 3].

Even when the need for restoring environmental responsibility to society has been recognized, creating reliable designs for incentives and institutions creating responsibility functions still remains difficult, although many mechanisms to implement such instruments have been proposed [5, 14]. Unlike engineering where technical innovations that can be transformed into prototypes and tested extensively before being put into practice, social innovations are often implemented while they are still in concept stage since the means to test their reliability have been limited [1,12]. Indeed, a large variability has been widely experienced in the performance of social and economic development agendas [13].

Mitigation Banking is a social innovation that is expected to restore the function of environmental responsibility in society, and many views exist about how a mitigation banking system should be organized, however, an objective evaluation of the various available organizational and regulatory options has never been carried out, which is attempted in this paper. A system dynamics model of a mitigation banking system is developed and its working under different regulatory and organizational frameworks possible under present technological, resources and organizational contexts tested through computer simulation. It is observed that mitigation banking is best implemented through a market system provided, of course, the quality of restoration carried out by a privately run mitigation organization can be assured.

2. What is environmental mitigation banking?

Many institutional concepts have been proposed to restore environmental responsibility in society once their need was recognized. Examples of these include the creation of private National Truststhat would purchase and maintain historical heritage and reserves; the imposition of Environmental Taxation on production of commodities so their price is modified in accordance with the environmental burdens they

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create; the trading of Emissions Rights so cost of environmental degradation can be borne by the responsible parties with the help of the market, and Mitigation Banking so environmental degradation is off set by a concomitant restoration effort while the cost of mitigation is borne by the parties who consume environmental resources. Whether these concepts can reinstate the environmental responsibility function in society cannot be ascertained, since designs based on these concepts have not been tested adequately to allow us to guarantee their success [7].

The compensatory mitigation concept supports the notion that the net environmental value of an area lost to development is maintained at zero. When mitigation is carried out within the developed area, a complete status quo in environmental resources can be maintained, but this may not always be a feasible solution. When development and mitigation areas can be geographically separated, the net environmental loss might still be maintained at zero while the loss and gain areas are different, and parties carrying out mitigation may also be different from the parties consuming environmental resources. However, if the cost of mitigation must still be borne by the party consuming environmental resources, while an equivalent value of environmental resources consumed is restored, the mitigation process may unify the objectives of avoidance, minimization and mitigation of environmental damage.

If the development and compensatory restoration areas must coincide, each developer must be required to mitigate the environmental damage she has caused. However, when development and mitigation areas may be different, a Mitigation Bank can be formed to carry out the mitigation work and sell the credits so earned to a developer. Such a mitigation process creates a trading system whereby deposits can be credited in advance of development by means of ecosystem creation or restoration. Since restoration effort might be concentrated in a selected area, this process can also help to alleviate ecosystem fragmentation. Also, since a bank can specialize in particular types of restoration work, restoration activity would be more reliable and ecosystem restoration failure may be avoided. Furthermore, unforeseen costs in case of direct restoration by the developers may be avoided since failure rate is progressively reduced as a mitigation bank develops technical expertise in its work. Last, but not least, since the regulation accompanying mitigation banking creates a cost for projects that degrade environment, they are likely to be implemented in a way that this cost and hence the accompanying environmental damage are minimized.

A mitigation banking system may function under a variety of organizational and regulatory arrangements. It can be established in the public or private sector. The price of mitigation credits it creates can be fixed through complex algorithms, tied to cost using engineering methods, supported by subsidies, determined by the market or influenced by all combinations of those factors. Many views exist on what might be an appropriate way for a mitigation bank to function. Currently, the establishment and use of mitigation banks are being promoted in many countries. In the United States, active mitigation banking systems are in place in Minnesota, Florida and California. In all cases, the implementation of the concept is in a nascent stage and its efficacy under a variety of arrangements needs to be carefully evaluated [8, 9].

3. Modeling a mitigation banking system

Key actors in a mitigation banking system include infrastructure developers engaged in creating built environment, mitigation banks engaged in creating mitigation credits by carrying out environmental restoration, regulatory institutions enforcing credit requirements on developers and pricing norms on mitigation banks, engineering institutions tying the price of mitigation credits to their costs, markets helping to clear a surplus or deficit of credits supply and demand through a free trading process, and the government intervening financially to change the pace of restoration and infrastructure building activities. These actors are a part of a model we have developed in this study to represent the interaction between environment, conservation and development. Experiments with this model address following agendas:

a) The evaluation of mitigation banking system operated by the state with fixed price of credits irrespective of mitigation cost. Government may or may not further subsidize mitigation work.
b) The evaluation of a mitigation banking system where public developers manage the public mitigation banks themselves, which often requires that mitigation costs are tied to the price of credits. Government may or may not subsidize mitigation work.
c) The evaluation of mitigation banking system in the case where a private developer purchases the credits from a private mitigation bank at a price determined by the market. Again, government may or may not subsidize mitigation work.

3.1 Overall map of the model

The model is divided into 7 sectors:

1) Infrastructure development
2) Mitigation Banking
3) A regulatory process for environmental preservation requiring acquisition of eco-credits for infrastructure development and maintenance
4) Mitigation credit pricing
5) Market based pricing inputs
6) Cost based pricing inputs
7) Government support

The interaction among these sectors is shown in Figure 1. Government intervention in terms of subsidization of mitigation activity is exogenously determined and is assumed to be non-earmarked so it directly enhances the mitigation bank's cash position.

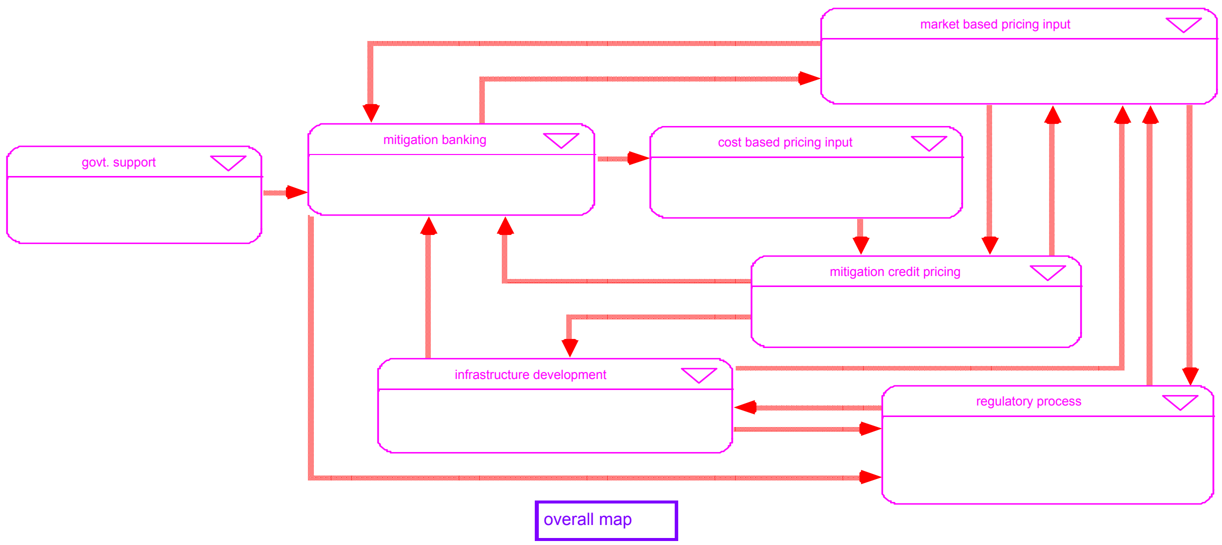


Figure 1: Overall map of the model

Infrastructure development is driven at the outset autonomously as a fraction of the existing level of infrastructure, but is restrained by the price of mitigation credits when a credit system imposed by a regulatory process is in place. Infrastructure development drives environmental restoration while its need for eco-credits limits its own activities. A regulatory process can be imposed on the infrastructure development sector requiring it to buy mitigation credits for its infrastructure maintenance and building activities that consume environment. The infrastructure development sector is allowed to acquire these credits on a pay as you play basis so it maintains an appropriate credit balance based on its use of credits. Also, for simplification, credit requirement per unit of infrastructure is assumed to be fixed, although in reality it might decline as cost consideration lead to less degrading building processes.

The mitigation banking sector acts as an environmental restoration agency, accruing mitigation credits for the restoration work and selling them to the developers at a price. It undertakes restoration work in expectation of profit when market offers a high price for mitigation credits. It can potentially be influenced by government subsidies which are assumed to be non-earmarked, i.e., they are assumed to flow into the mitigation bank's cash balance which is applied to projects in expectation of profit and hence the undertaking of such projects is influenced by price of credits.

The price of mitigation credits may be fixed, determined by cost considerations, determined by the market or by a combination of cost-based and market considerations. Restoration cost is assumed to depend on the extent of damage to be repaired represented in the model as a functionality ratio. A base price that may be either be fixed or tied to restoration cost is then modulated by supply and demand of the credits when the banking system is assumed to operate through the market. These sectors are described in detail in the following section.

3.2 Model structure

3.2.1 Infrastructure development sector. Figure 2 shows the infrastructure development sector, which is modeled as a supply chain that is in equilibrium when infrastructure building starts, completions and decay rates balance. Infrastructure building starts are a fraction of infrastructure in place and are exogenously stepped up to test model behavior. Infrastructure building starts are constrained by the supply of infrastructure credits when credit requirement regulation is in place. The building starts are also fueled by the sector's financial position determined by its need and supply of cash, which is a measure of the industry profitability. Infrastructure development sector's income is accrued from user fees and its expenditure is made on accounts of construction and maintenance costs and the moneys paid for acquisition of mitigation credits.

3.2.2. Mitigation banking sector. Figure 3 shows the structure of the mitigation bank carrying out environmental restoration. Restoration process is modeled also as a supply chain involving restoration delays. In equilibrium, restoration rate is assumed to equal the decay rate, which depends on infrastructure construction and maintenance operations. Restoration starts on the other hand depend on the funds available to the bank, unit mitigation costs, and the price of mitigation credits that drives expectations of the bank to turn profit. Restorations can also potentially be driven by earmarked subsidies, which can result in projects irrespective of credit price that drives profit expectations, but these are excluded from our model for simplification. The bank income depends on the value of credits sold, and any non-earmarked subsidies in the form of mitigation funds disbursed by the government, international organizations or other interest groups. The mitigation bank expenditure consists of administrative overheads and restoration costs.

The mitigation bank earns credits for any restorations carried out. These credits can be sold at prices that may be fixed, cost dependent, determined by the market, or by any combination of these considerations. The bank does not withhold credits it has already earned when their price is low, but it would slow down its restoration starts.

3.2.3 Regulatory process for environmental preservation. When a regulatory process requiring developers to support mitigation through acquisition of eco-credits is in place, a developer would maintain a credit balance depending on the volume of infrastructure he builds and maintains. Figure 4 illustrates how this process is modeled.

The developer credit balance is increased through credit acquisition and depleted through credit use. Credits are used up when new infrastructure is constructed or existing infrastructure is maintained. These are constantly acquired based on the discrepancy between the existing balance and desired balance necessitated by their rate of consumption. A shortage of credits creates a constraint on developmental work.

3.2.4. Mitigation Credit Pricing. An important part of mitigation banking is the determination of credit price. The credit price can be fixed by the government, tied to costs, left to market forces or based on a combination of all three considerations. All possibilities and their combinations are incorporated into the mitigation credit pricing sector shown in Figure 5. When cost based and market based pricing inputs are not included in the model, the price returned by this sector will be fixed, otherwise it will be influenced by one or both of those inputs depending on their activation. The actual price adjusts towards an indicated price determined by selected considerations.

3.2.5. Cost-based pricing input. When credit price is tied to restoration cost, engineering considerations will constitute an important input to the pricing process. Given that the discrepancy between the desired and actual condition of functional environment will strongly influence restoration cost, the cost based pricing input is tied in the model to a functionality ratio comparing actual and desired environmental conditions as shown in Figure 6. A complex engineering-based pricing model should replace this relationship if cost based pricing input is considered important to the pricing process.

3.2.6. Market-based pricing input. When credits can be bought and sold freely in the market, the base price is further modulated by supply and demand conditions modeled as shown in Figure 7. When the demand for mitigation credits is higher than supply, their price goes up which fuels mitigation work increasing eventually credit supply. On the other hand, the developers would defer buying credits and maintain a lower credit stock when credit price is high. The intrinsic demand for credits arises from development and maintenance needs and the need to maintain an inventory of credits to smoothly support developmental work. The desired and actual credit inventory determines credit availability, which modulates their price.

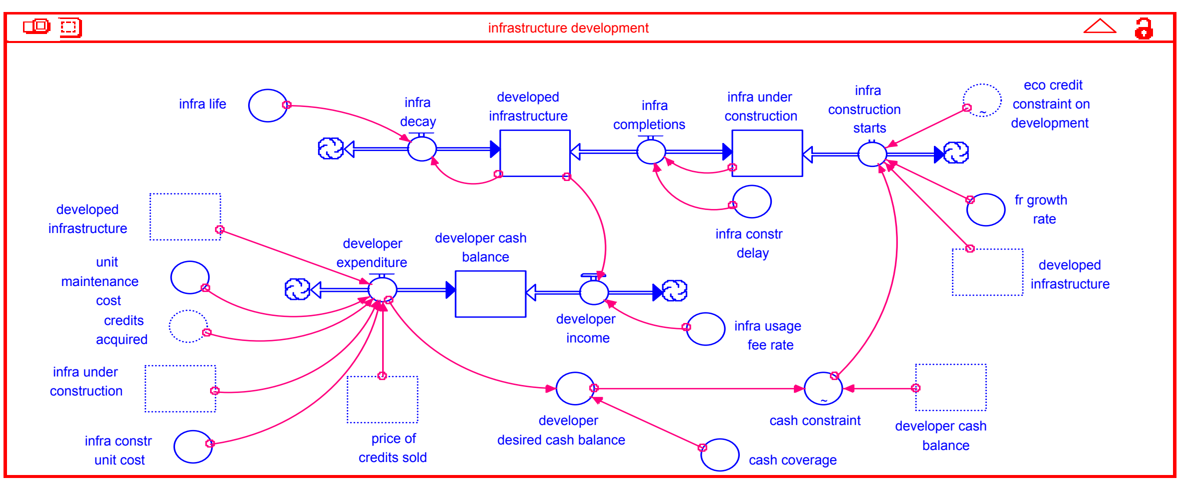


Figure 2: Infrastructure development sector

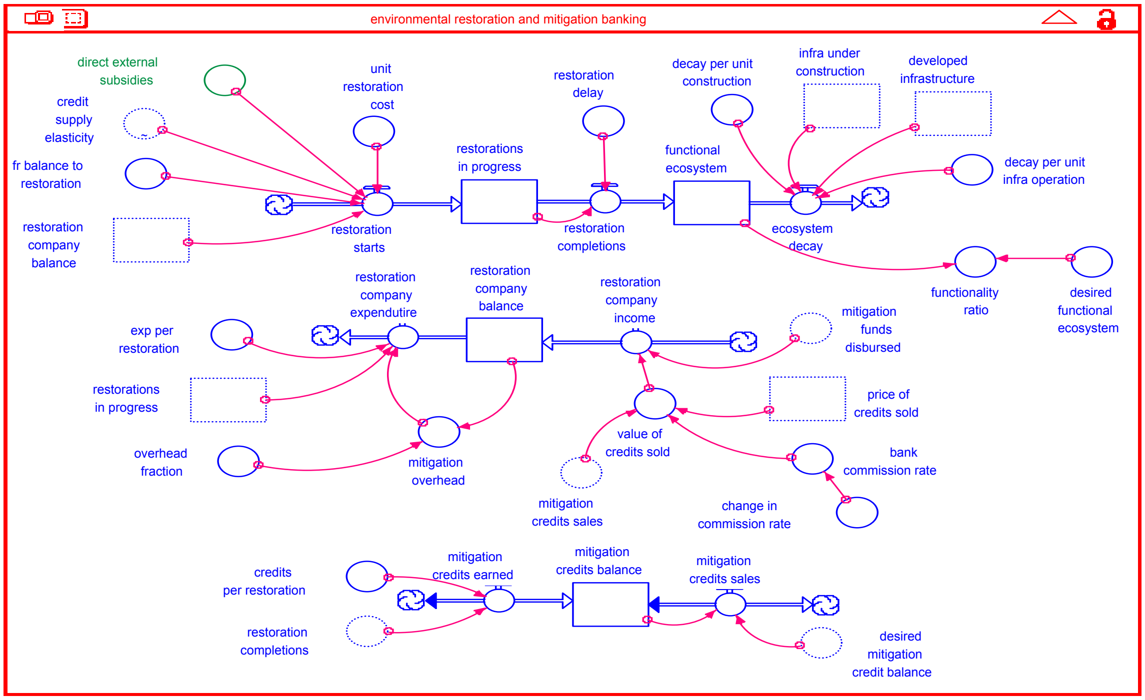


Figure 3: Environmental restoration sector

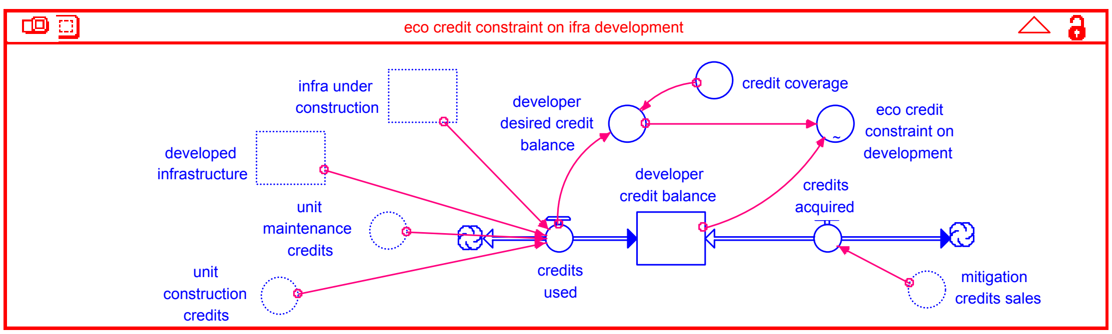
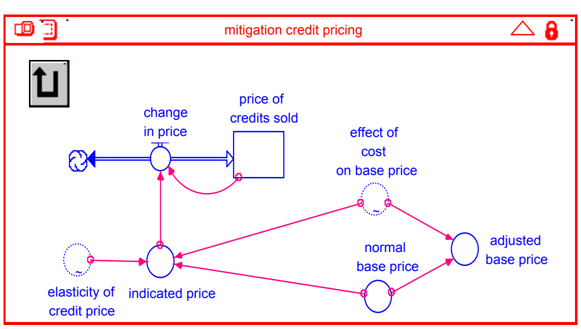


Figure 4: A regulatory process involving acquisition of eco-credits for infrastructure development and maintenance



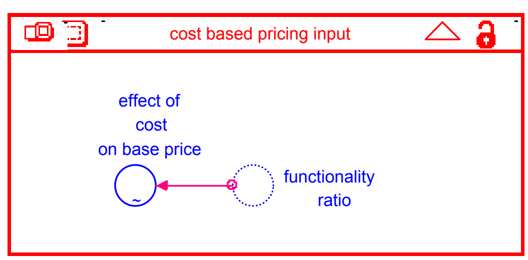


Figure 6: Cost-based pricing input

Figure 5: Determination of mitigation credit price

3.2.7. Government support of restoration activities. The government sector of the model is represented by a single exogenously determined input, namely non-earmarked support shown in Figure 8. While earmarked support implies subsidies specifically earmarked for selected restoration work and provided independently of profit considerations of the mitigation bank, non-earmarked support is assumed to subsidize the mitigation bank in general, improving its resources so it can invest them for restoration work in cognizance of profit considerations.

In actual practice, the government may maintain a mitigation fund that may be disbursed to subsidize restoration work of the mitigation banks. The government may channel a part of the general taxes collected, a levy on infrastructure user fees and any external contributions into the mitigation fund. The fraction of general tax collection channeled into mitigation fund may also be influenced by the environmental functionality ratio, a poor environmental condition evoking a higher fraction. Since only the effect of the subsidies is investigated by this paper, their determination is not modeled. Also, only non-earmarked general subsidies are considered for simplification.

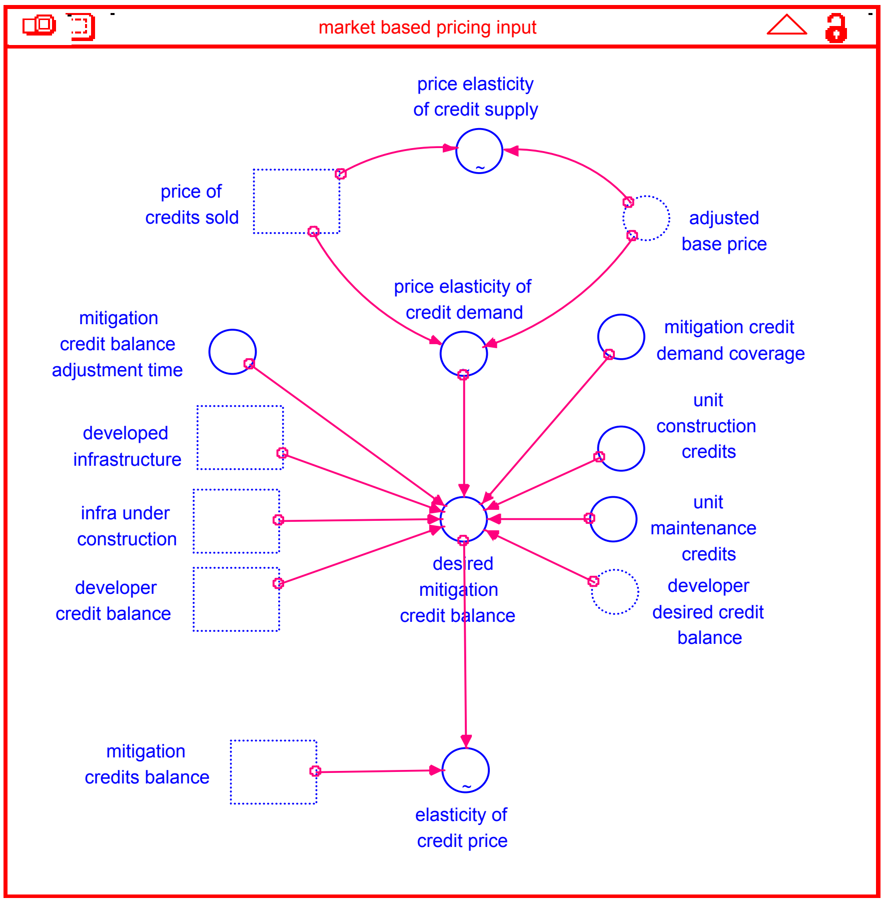


Figure 7: Market based pricing input

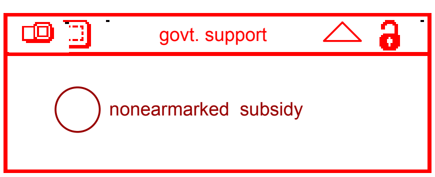


Figure 8: Direct government support of mitigation activity

Table 1: Sector configurations in the reported model experiments

Experiment	Processes included in the model: Development	Mitigation banking	Mitigation regulation	Cost based pricing inputs	Market based pricing inputs	Govt. subsidization of mitigation
1	O	O	O			
2	O	O	O			O
3	O	O	O	O		O
4	O	O	O	O		
5	O	O	O	O	O	
6	O	O	O		O	
7	O	O	O		O	O

4. Experimentation with the model

The model was initialized in equilibrium with the government support and cost and market based pricing inputs to mitigation credit price excluded keeping the price of mitigation credits fixed. This amounts to the presence of mitigation credit system but with fixed price and an absence of any fiscal intervention by the government. Infrastructure development fraction was exogenously stepped up. Several experiments were conducted by simulating the model by varying the number of interacting sectors, each representing an organizational or a regulatory assumption. Seven of these experiments outlined in Table 1 are reported in this paper.

4.1. Experiment 1: Fixed price of credits with mitigation regulation

When mitigation regulation is enforced and the price of credits is kept fixed, the functional ecosystem continues to decay when infrastructure is developed, but as infrastructure development becomes restrained by the availability of eco-credits, both infrastructure development and ecosystem decay slow down. This is shown in Figure 9. As environmental decay increases, mitigation costs rise while mitigation bank income is limited by the fixed price of credits. This results in inadequate supply of credits and possibly bank failure. Infrastructure development is at first limited due to eco-credit constraint and eventually goes into a decay spiral created by development being tied to its current level.

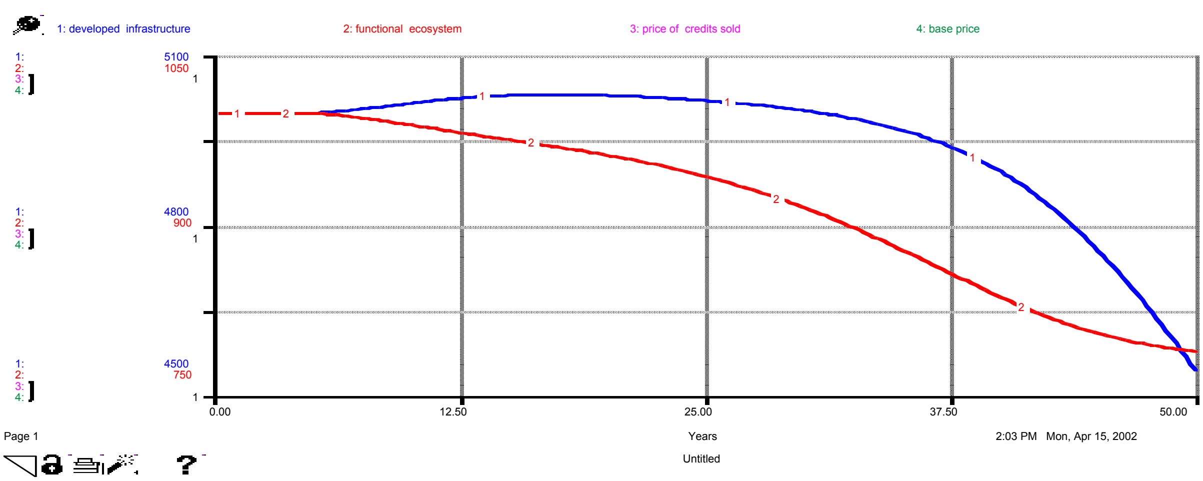


Figure 9: Model behavior with fixed price of mitigation credits and enforcement of mitigation regulation

4.2. Experiment 2: Fixed price of credits with mitigation regulation, and with non-earmarked government subsidies to mitigation bank

When mitigation banking cannot be sustained, the public cry is often for government subsidization of the mitigation banking system, which this experiment explores. Figure 10 shows the simulated behavior in this experiment. Sustained improvement in functional environment is noted, but a growth and collapse behavior in infrastructure development appears due to the drain on cash created by the maintenance of overdeveloped infrastructure, and an undersupply of eco-credits created by rising cost of mitigation and under-estimation of credit need from pay as you play behavior. A downturn spiral takes over after the peak since incremental development depends on its existing level.

4.3. Experiment 3: Mitigation regulation with price of credits tied to mitigation cost, and with non-earmarked government subsidies given to mitigation bank

In this experiment, the price of mitigation credits is allowed to vary according to the cost of mitigation given by the normal price and an influence of functionality ratio, meaning that a larger discrepancy between current and desired condition of environment would require a greater effort per unit of restoration. Figure 11 shows the behavior of the simulation in the experiment. Infrastructure growth is propelled due to low price of mitigation credits, but collapses due to a downward spiral created by internally determined construction goals. Credit market is not cleared and over production of credits creates financial bottlenecks for the mitigation bank. Oscillations appear in the stock of functional environment and the price of credits since the two follow each other with a time lag. Also, the adjustment of price and the development and mitigation rates have adjustment delays and phase lags that create considerable over and undershoots which would create unpleasant social and economic impacts.

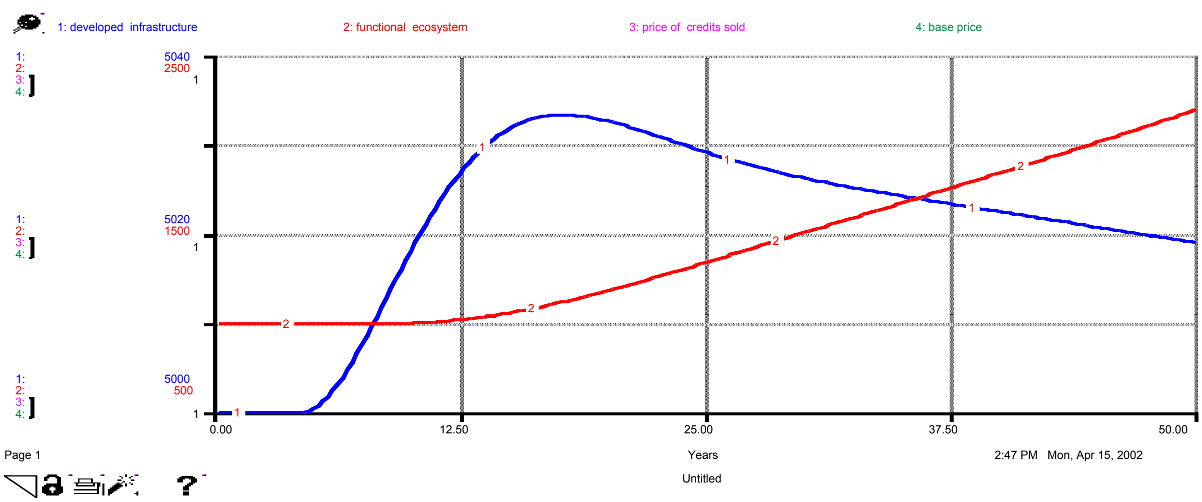


Figure 10 Model behavior with fixed credit price and subsidization of mitigation by government

4.4. Experiment 4: Mitigation regulation with price of credits tied to mitigation cost, but without non-earmarked government subsidies to mitigation bank.

When government subsidy is withdrawn, while the mitigation bank is allowed to tie the price of credits to the cost of restoration, we have an equivalent of a public sector bank operated as an autonomous nonprofit organization. Figure 12 shows the simulated behavior in such a case.

Infrastructure growth rates are moderate and overshoot and collapse behavior in infrastructure sector and mitigation banking is avoided, however, sustained oscillations appear in infrastructure, functional environment and price of credits due to adjustment delays in the system. Ecosystem and infrastructure conditions oscillate with almost a 180 degree phase difference.

4.5. Experiment 5: Mitigation regulation with base price of credits tied to mitigation cost, market clearing of price of credits and without non-earmarked government subsidies to mitigation bank.

When the credit prices are also allowed to be cleared by the market implying that the credits can be traded like stocks, a more functional behavior appears as shown in Figure 13. Sustained growth in built environment moves towards a plateau with concomitant maintenance of environment. Market pricing of credits sustains both mitigation banks and developers with some fluctuations due to adjustment time lags. Overshoot and collapse behavior is avoided. The market clearing process helps to align developmental and mitigation activities relatively rapidly, allowing a sustained growth in built environment as well as maintenance of reasonable ecosystem quality.

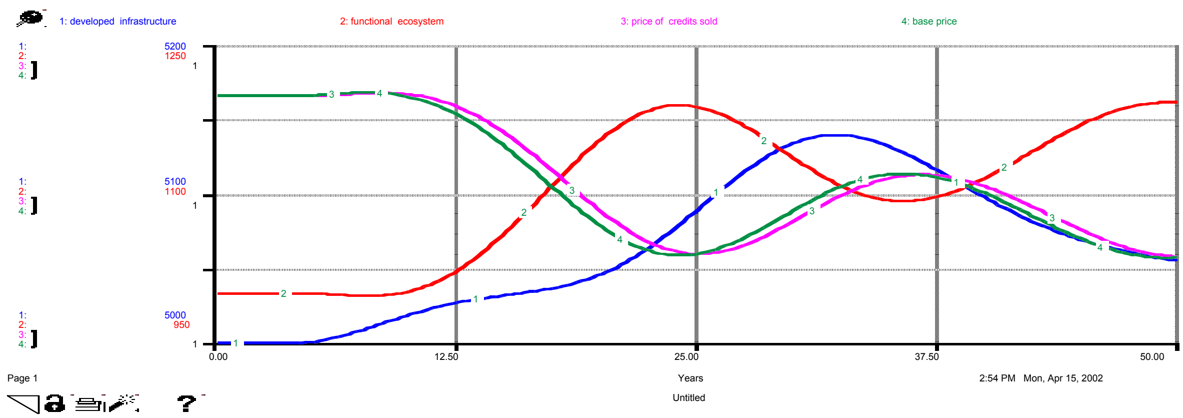


Figure 11: Model behavior with govt. subsidization of mitigation and with price of credits tied to cost of restoration

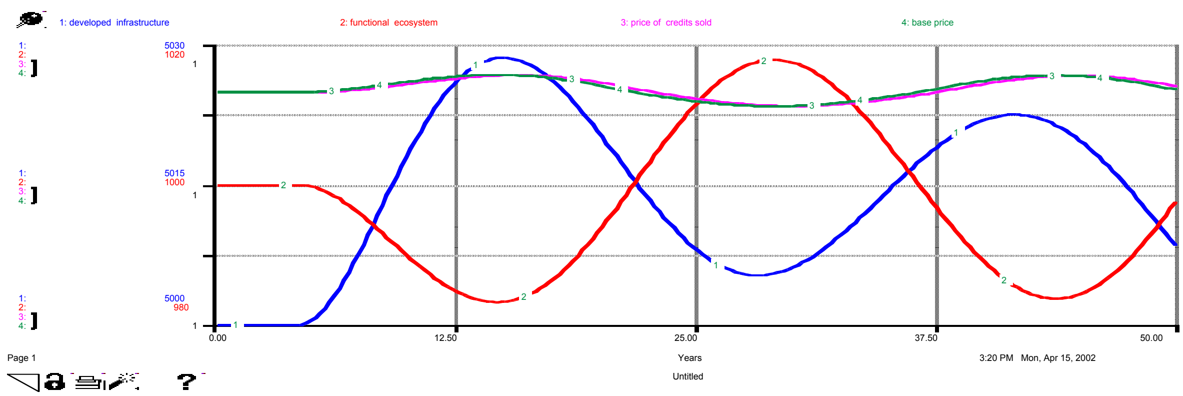


Figure 12:Model behavior without government subsidization, but with cost of credits tied to restoration cost

4.6. Experiment 6: Mitigation regulation with price of credits determined only by market and without non-earmarked government subsidies to mitigation bank.

Once the effectiveness of the market in continuously modifying the price of credits, their demand and production to align developmental and mitigation activities has been recognized, it is instructive to test the possibility of doing away with cost based pricing since it would involve a complex computational process. Figure 14 shows a simulation in which the price of credits is unlinked from cost and is determined solely by the market. Both infrastructure growth and environmental functionality improve over a more stable path than the case when cost considerations in pricing of credits also factor in, while environmental functionality reaches a higher value and price of credits stabilize more quickly. Apparently, market helps to arrive at an optimal price that supports both infrastructure development and environmental mitigation work, eventually aligning price of credits to the cost of mitigation without requiring a complicated cost based accounting, which is good news since such accounting can be expensive as well as controversial.

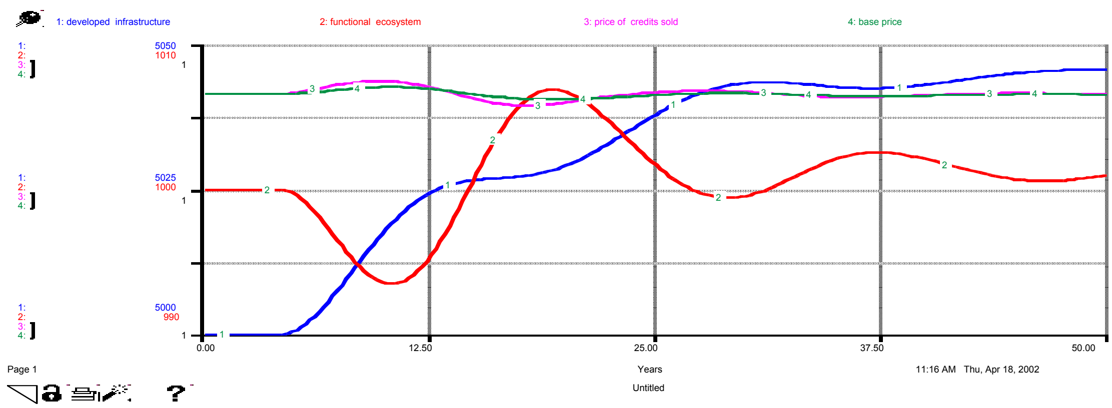


Figure 13 Model behavior with credit prices determined both by functionality of ecosystem and market clearing

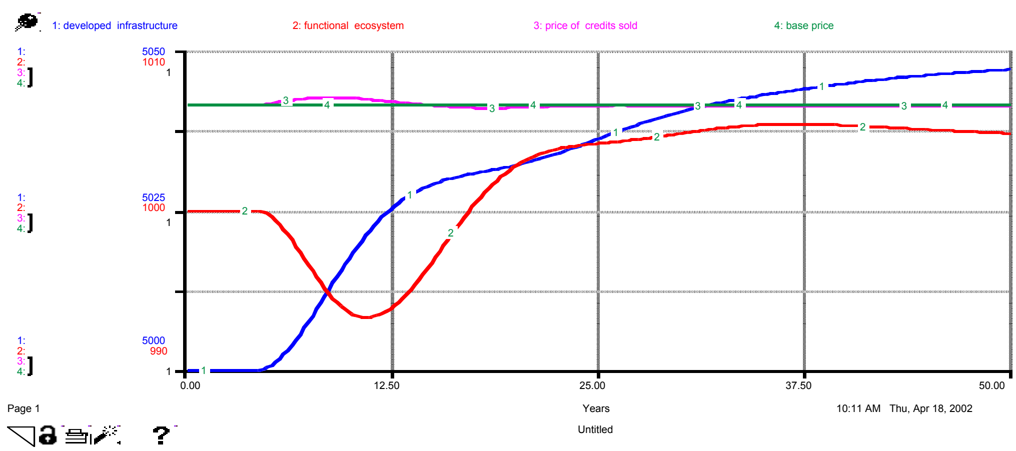


Figure 14: Model behavior with mitigation regulation and credit price determination through market only

4.7. Experiment 7: Mitigation regulation with market determination of price of credits and with non-earmarked government subsidies to mitigation bank.

Government subsidization of environmental restoration on top of market clearing of price of eco-credits reduces price of credits, which fuels infrastructure development while also improving environmental quality as shown in Figure 15. However, this subsidy transfers a part of general tax collection to a gain for the developers and the beneficiaries of the infrastructure. The incidence issue so created needs to be further studied.

Above experiments show that a mitigation banking system can successfully perform all three functions, avoidance of environmental damage, minimization of damage and restoration of decayed environment. The first two functions are served through increase in the cost of built environment when building creates decay, which slows down growth of built environment. The last function is manifest in the compensatory restoration undertaken before environmental credits can be applied towards development projects that consume environment

5. Limitations of the study

The model developed in this paper has, however, several limitations. First, infrastructure development is modeled as a supply-side activity while in reality the demand for infrastructure is generated by the economy while infrastructure availability influences economic growth. While this feedback is approximately captured by the dependence of infrastructure growth on infrastructure stock, the delays in the process are not captured. A simple model of the economy should be added to the existing model to represent demand generation for infrastructure. Second, the quality of restoration is assumed to be always satisfactory, whereas in reality it might be influenced by financial, organizational and technical considerations, which need to be investigated. Third, the extent of damage a developer may cause might be sensitive to the price of credits, which will create more careful construction techniques, if it is high. This aspect of development needs to be further investigated. Fourth, government intervention can be implemented in a variety of ways, including general support of mitigation organizations, support of selected projects, allocation of general taxation to general or earmarked support of mitigation, remedial taxation of infrastructure, price support for mitigation credits, etc. Likewise, private organizations might also be involved in the finance of mitigation activity in a variety of ways. The impact of all such options needs to be further investigated. Fifth, when mitigation area is geographically separated from development area, there appears the issue of costs and benefits accrued to the various cross-sections of the population, which should determine the bounds for the operation of the mitigation system. This needs to be carefully delineated. Last, but not least, the mitigation banking concept has to date been applied largely to wetlands and forests. Its relevance to other types of environment needs to be investigated.

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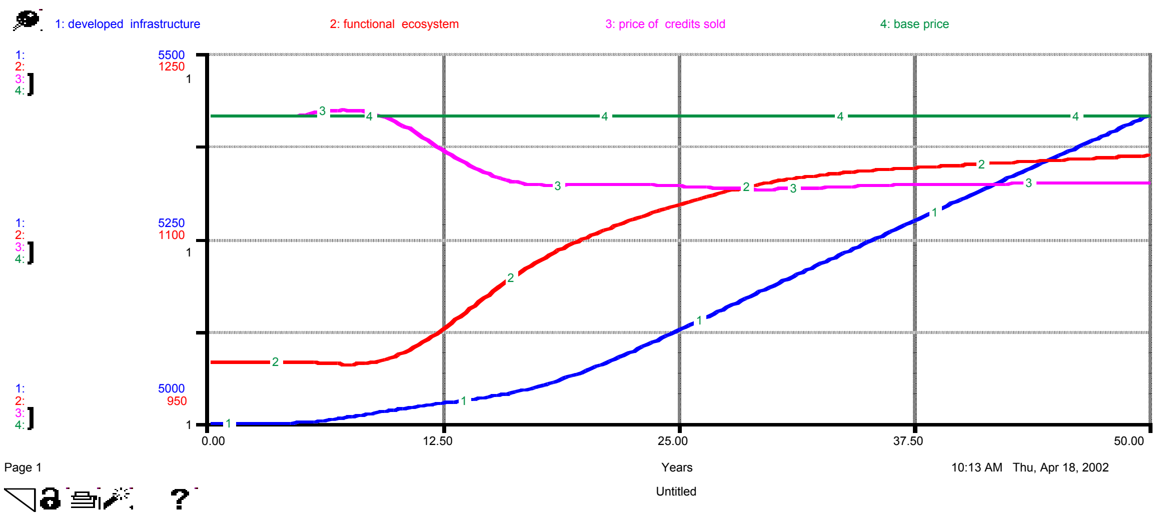

Figure 15 Model behavior with both market determination of credit price and govt. subsidization of restoration

6. Conclusion

The analysis of this paper first of all provides a way to test the design of societal innovations before they are implemented so their impact has fewer surprises. A system dynamics model of a mitigation banking system is developed and experimented with under different organizational and regulatory conditions. Experiments with the model show that market pricing of the credits might be the easiest and the most effective way to assure reliable functioning of the mitigation banking system that should support growth of built environment to a sustainable level while the functionality of physical environment is preserved. Government subsidization of mitigation may create a more rapid growth in built environment, which in certain instances might create an overshoot and decline. The model seems to perform satisfactorily in these preliminary experiments. Many more extensive experiments need to be conducted with the model to understand the role of the government, the modes of its support for mitigation activity and the impact of various regulatory policies. Furthermore, the model has many limitations that are outlined in the paper. Further work should address those limitations.

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